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Code.Ino: An Educational Game for Arduino Programming with Female Protagonism to Encourage Diversity in STEM

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The use of digital games in teaching programming is a powerful strategy to engage students in a playful and meaningful way. By transforming abstract concepts into interactive challenges, games stimulate curiosity, creativity, and logical thinking—elements essential for learning computing. In this context, this article presents the educational digital game *Code.Ino* for teaching Arduino programming. This game was developed to teach programming playfully to middle and high school students, using female protagonism as a strategy to encourage diversity in STEM (Science Technology Engineering Mathematics). The game features interactive challenges and engaging narratives, divided into ten levels that cover concepts of hardware and software in Arduino, while also highlighting important women in the history of Computing. An initial evaluation with students and teachers showed a positive reception of the tool as an interesting and motivating didactic resource for learning Arduino programming.

Keywords: Code.Ino, Educational game, Arduino programming, Female protagonism, STEM, Computational thinking.

1 Introduction

Teaching programming in schools goes far beyond training future technology professionals—it is about preparing children and young people for an increasingly digital world. Programming develops logical reasoning, problem-solving skills, creativity, and, most importantly, promotes digital fluency, an essential skill in this century [Victal *et al*., 2015; Medeiros *et al*., 2020; Silva and Falcão, 2020; Garcêz and Oliveira, 2022]. By learning to program, students not only understand how technology works but also become creators, not just consumers of digital content [Resnick *et al*., 2009].

In this process, Garcêz and Oliveira [2022] states that the use of educational games stands out as a powerful teaching and learning tool. By transforming content into fun and interactive challenges, games make learning more engaging, awakening student's natural interest. In a playful environment, students experiment, make mistakes, succeed, and learn in a light and meaningful way, also developing important project and collaboration skills.

Thus, Uzunca and Jansen [2016] argue that games should be used as a teaching tool, as they enable: (i) learning in a virtual reality and/or with simulated roles, which encourages the player since they can always restart; (ii) 'learning by doing,' involving, motivating, and entertaining; (iii) the possibility of stimulating the ability to find and use information without the need for memorization; and (iv) the simulation of complex/expensive environments and dangerous/critical situations.

Promoting the teaching of programming to children through playful and interactive methodologies enables new generations to acquire the tools necessary to understand, transform, and lead the digital world. And it is at this intersection of education, technology, and creativity that the educational digital game *Code.Ino* was developed and presented in this article. This game aims to support the teaching-learning process of programming through Arduino.

Arduino is an open-source electronics prototyping platform based on easy-to-use hardware and software. The hardware consists of a microcontroller with input and output circuits, making it a low-cost, efficient device that is easy to program and adheres to the concept of open hardware. Once programmed, the board can be used independently. Among its many uses, Arduino can control robots, electronic devices, and other projects that involve programming and hardware. With Arduino, students can create tangible projects such as robots, sensors, and automated systems, providing practical learning where programming ceases to be just an abstract concept on the screen and takes concrete form, reinforcing learning and stimulating curiosity.

Thus, considering efforts to provide effective and engaging teaching for middle and high school students, the authors of this work present the conception and development of the educational digital game *Code.Ino*, whose use aims to support the teaching-learning process of programming through Arduino. This game should enable students to understand the concepts involved, both in the hardware and software aspects of Arduino.

The development team of the *Code.Ino* game is composed solely of women, who designed a game for all genders, but intentionally centered female characters to normalize women's participation in tech and challenge gender biases. Thus, in all stages of the game, the protagonism of a woman who made an essential contribution to the STEM (Science Technology Engineering Mathematics) field is highlighted. Moreover, in *Code.Ino's* digital universe, only girls embark on the journey of learning to program, supported by the guidance of an experienced teacher. This careful construction of the game was

intended to make girls feel at home in the world of computing, especially in digital games.

This article is an extended and revised version of the original paper [Castro *et al*., 2024], presented at WIT (Women in Information Technology) 2024, an event of the Brazilian Computer Society Congress. The WIT version included only the first two levels of the *Code.Ino* game. To present all the levels and a survey with over 50 players, this article is organized, besides this introduction, into seven more sections. Section 2 details the theoretical foundation of this proposal. Section 3 describes related works. Next, Section 4 presents the *Code.Ino* game and details of its development. Section 5 shows the methodology used in the development of *Code.Ino*. Section 6 details the ethical procedures adopted during the research. Section 7 describes the evaluation of the game, which was conducted to assess the interface and gameplay of *Code.Ino*. Finally, Section 8 presents the conclusion and some future work.

2 Contextualization

Programming is the verb used to represent the action of constructing algorithms, which can be understood as a sequence of steps aimed at transforming inputs into outputs [Cormen and et al., 2002]. Thus, if the appropriate methodology is not used, the teaching-learning process of programming logic can be arduous. In this sense, innovations in teaching tend to facilitate and assist the acquisition of knowledge in this area. Silva & Falcão [2020] argue that playful educational methods can be a facilitating resource.

In this context, Arduino is a microcontroller platform that has gained enormous popularity, mainly due to its ease of use and open nature. Arduino is an open-source prototyping platform that combines hardware and software components, making them easy to use [Arduino, 2025b]. Thus, Arduino enables the development of so-called 'physical computing' through the connection of its electronic circuits to its terminals, aiming at controlling devices such as LEDs and motors; or measuring variables such as temperature and luminosity [de Medeiros and Wünsch, 2019].

The Arduino Uno is one of the most popular boards in the family. It features a 16 MHz processor, 2 KB of RAM for data storage, and 32 KB of *flash* memory for programs [Arduino, 2025a]. Additionally, it offers 28 I/O ports for connection with various external devices, allowing the reading of inputs, such as light from a sensor or a message on Twitter, and the transformation of these inputs into outputs, such as activating a motor.

However, for the circuits used with Arduino to operate, a program must be uploaded to its microcontroller. Programming for Arduino is done using a development environment based on the C++ language, adapted for the platform. After developing the code, the programmer must load it onto the Arduino, where it is stored in the *flash* memory.

Thus, choosing Arduino as a strategy to teach programming to school students is an effective and engaging way to make abstract concepts more concrete and accessible [Maia *et al*., 2023]. Arduino allows students to see, practically and immediately, the results of the code they write, such as lighting LEDs, moving motors, or measuring temperature, significantly increasing interest and motivation. Additionally, working with sensors and actuators helps students develop skills in logic, problem-solving, and computational thinking, while also understanding how technology can be used to create real-world solutions for everyday life [de Medeiros and Wünsch, 2019].

In this context, the game *Code.Ino* was proposed as a digital tool to teach Arduino concepts to middle and high school students, utilizing *smartphones* as the platform. With an interactive and engaging approach, the game aims to spark interest in programming and electronics creatively and inclusively, enabling students to explore the world of technology through contextualized challenges and engaging narratives. It integrates youth language with the fundamentals of Computing, *Code.Ino* seeks not only to teach but also to empower young students, showing that everyone has a place and protagonism in the world of technology.

3 Related Works

In recent years, the use of digital games as a teaching tool has gained prominence in various areas of education. This approach aims to make learning more engaging, interactive, and accessible, especially for beginners, by combining computational concepts with playful and challenging elements [Silva *et al*., 2021; Ortega-Arrieta and Dávila, 2023].

Thus, this section presents some initiatives that address the use of digital games in teaching programming and technology. The objective is to contextualize the development of *Code.Ino* as a support tool for teaching programming, highlighting the similarities, differences, and specific contributions of recent works that also aim to promote learning in a playful and accessible way.

The game *Peg.Ada* [Vinhal and Odakura, 2023] was developed to teach high school and university girls about digital footprints, which are data traces that Internet users intentionally or unintentionally leave behind [Micheli *et al*., 2018]. The proposal focuses on guiding girls in ethics and digital security, exemplifying how they should handle certain inappropriate situations on the Internet. The game addresses a relevant theme but does not focus on teaching programming.

In [Rocha Sobreira *et al*., 2018], a digital game was developed using the *Scratch* language to teach about energy sources and their applications. The research was conducted with 23 fifth-grade children, who were approximately 10 years old. Thus, these children used the game to help understand energy consumption on prototyping platforms such as Arduino and *Makey Makey*. However, the students who participated in the research already had prior knowledge related to robotics and Arduino.

In [Tupac-Yupanqui *et al*., 2021], the use of Arduino and the prototyping platform *Tinkercad* was introduced for first-year students at Universidad Continental de Huancayo in Peru, during the COVID-19 period, to develop programming skills for Engineering and Technology courses. This proposal resulted in significant learning, with about 90% of students reporting that the use of Arduino helped in understanding basic programming concepts. The disadvantage of this

Table 1. Comparison between related works.

Paper	Game focus	Teaches Programming	Mobile	Quiz	No knowledge required	Female Protagonism
Scratch Energias [Rocha Sobreira *et al*., 2018]	Teaching energy concepts with Arduino for children	Yes	No	No	No	No
Tinkercad + Arduino [Tupac-Yupanqui *et al*., 2021]	Arduino Programming Skills Development for College Students	Yes	No	No	No	No
Mundo Bit Byte [Araujo *et al*., 2022]	Dissemination of the female legacy in Computing	No	Yes	No	Yes	Yes
Peg.Ada [Vinhal and Odakura, 2023]	Digital Ethics and Safety Awareness for Girls and Desktop	No	No	No	Yes	Yes
OurPlace: Amazing Grace [Nizer *et al*., 2024]	Female inspiration in STEM through the story of Grace Hopper	No	Yes	No	Yes	Yes
Guess Teaching [Furquim *et al*., 2025]	Teaching Libras for social inclusion	No	Yes	Yes	Yes	No
Code.Ino (This paper)	Teaching programming with Arduino and empowering women in STEM through practical challenges	Yes	Yes	Yes	Yes	Yes

approach is that it requires students to have prior knowledge of the subject.

In [Briceño *et al*., 2021] and [Araujo *et al*., 2022], the game Mundo Bit Byte is presented, a 2D platformer developed with the intention of giving protagonism to women in the history of Computing. The game was evaluated by 511 participants in two testing rounds, mostly young people between 10 and 25 years old. Although it proved effective in promoting female historical figures such as Ada Lovelace and Carol Shaw—who were unknown to most players before the experience—the game does not focus on a specific age group, nor does it address teaching programming languages, which is precisely the focus of the proposed work's game.

The game *Guess Teaching* [Furquim *et al*., 2025] shares with *Code.Ino* the approach of democratizing knowledge through mobile platforms, but with different focuses: while the former aims to break communication barriers for the deaf community through teaching Libras, *Code.Ino* seeks to reduce gender disparities in STEM. Both employ active methodologies and gamification, with *Guess Teaching* using quizzes and *Code.Ino* combining quizzes and practical projects, reinforcing the commitment to educational accessibility.

Similarly, *OurPlace: Amazing Grace* [Nizer *et al*., 2024] and *Code.Ino* aligns in promoting female protagonism in technology, but with complementary strategies: the former highlights historical figures such as Grace Hopper through point-and-click narratives, while *Code.Ino* offers practical Arduino programming experiences featuring female characters. This duality between historical inspiration and practical application fosters a more robust ecosystem that engages girls in STEM.

However, unlike most of the games presented in this section, *Code.Ino* was developed for the Android mobile platform and does not require prior programming knowledge to understand the game. Additionally, the game presented in this article aims to be a tool to assist in learning programming while also helping with projects and solving real-world problems. It will be possible to learn both the theoretical and practical aspects within the same game—another advantage of *Code.Ino* compared to the previously mentioned works, does not need an Internet connection to play or physical Arduino boards to understand their functioning with *Code.Ino* users can learn Arduino anywhere and at any time, requiring only a smartphone, which is the most commonly used platform among the female audience for gaming [Business, 2024].

4 Code.Ino Game

Code.Ino is an educational digital game developed for the *mobile* platform. Its primary goal is to serve as a supportive tool in the teaching and learning process of Arduino programming for middle and high school students. Thus, the proposal is that the player learns, in each level of the game, the components of an Arduino board and the logic involved in data processing creatively and playfully. In the final level

of the game, the player should be able to implement a complete project based on the knowledge acquired throughout the levels. As a result, it is expected that *Code.Ino*, when used as a supportive tool in programming classes, optimizes the teaching-learning process of programming in basic education schools.

The game has been developed by a team of female undergraduate students, utilizing the Unity engine[1] and the C# language. Thus, with *Code.Ino*, the player will learn programming logic and the basics of the C++ language, which is used in Arduino. To help players grasp the concepts of Arduino hardware and software, including programming and its components, the game is divided into ten levels, providing a playful learning experience. Each level aims to teach a component related to Arduino. After teaching each element, a quiz is used to assess the level of knowledge acquired by the user based on what was taught. Figure 1 shows the main screen of *Code.Ino*, which contains a button to start the game (JOGAR), one for the tutorial (TUTORIAL), and a button to exit the game (SAIR), as shown in Figure 2.

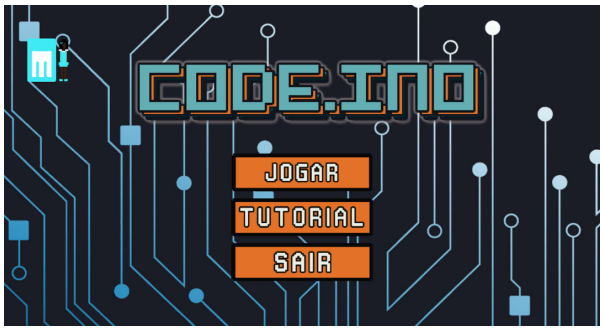

Figure 1. *Code.Ino* Game, Home, Screen and Menu[2]

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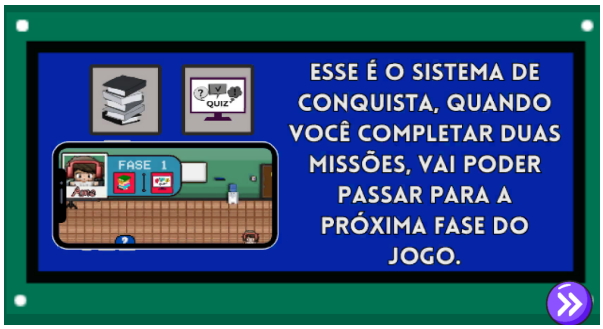

Figure 2. Tutorial screen explaining the achievement system[3]

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The chosen setting for the game is a school environment. It begins with the character Ame, who is the main character (shown in Figure 3). This character was inspired by the mascot adopted by Meninas.comp project [Silva *et al*., 2024; Araujo *et al*., 2023] at the University of Brasília (UnB).

The Meninas.comp project (*meninas* is the Portuguese word for girls) was created in 2010 with the mission of encouraging the participation of girls and young women in the field of Computing, breaking historical gender barriers, and demonstrating that this domain is also a legitimate space for them to dream, learn, and build impactful careers. Since its inception, the project has promoted workshops, lectures, courses, outreach events, and playful activities that bring Computing closer to girls in primary, secondary, and higher education, fostering self-confidence and a strong sense of belonging. The Meninas.comp is a partner project of the Brazilian Computer Society's (Sociedade Brasileira de Computação - SBC) national program Digital Girls (Programa Meninas Digitais - PMD) [Salgado *et al*., 2025].

Figure 3. The image on the left shows the original Ame (mascot of the Meninas.comp project), and the image on the right is the main character of the *Code.Ino* game.

The Digital Girls Program seeks to inspire girls—particularly senior middle and high school students—to explore the field of Computing and to encourage them to pursue careers in this area. According to the most recent Annual Partner Project Report [Araujo *et al*., 2025], the program currently includes 110 partner projects across Brazil. The Southeast region hosts the largest share (39), followed by the South (19). Altogether, these initiatives involve more than 2,000 team members. Further information is available on the official PMD website[4]. This way, the Meninas.comp is part of a nationwide network of initiatives, consolidating itself as a reference in promoting gender diversity and equity in the field, while inspiring new generations of women to play a leading role in science and technology.

So, at the start of the game, Ame (a character from the project Meninas.comp) moves to her school and discovers a robotics project called Meninas.comp. Thus, Ame begins her participation in the project as an extracurricular activity to learn more about robotics and Arduino programming at school.

From this point on, the player has the option to choose where Ame will go within the room. The right side of this environment can be seen in Figure 4, and the left side is shown in Figure 5. Depending on the path she takes, options appear for her interactions with objects or with other characters in the game. In this way, *Code.Ino* guides Ame to a new stage based on her interactions with the environment.

In the *Code.Ino* game, the computing project taking place at the school is coordinated by teacher Carla, known as Carlona. When Ame attends the first class, she is impressed and happy to discover that several other girls are involved in this project and working with programming in the laboratory. Ame's surprise occurs because she had imagined she

[1] `https://unity.com/pt`

[2] Translations for the menu buttons: JOGAR (Play), TUTORIAL (Tutorial), SAIR (Exit).

[3] Translation: THIS IS THE ACHIEVEMENT SYSTEM, WHEN YOU COMPLETE TWO MISSIONS, YOU WILL BE ABLE TO MOVE TO THE NEXT PHASE OF THE GAME.

[4] Programa Meninas Digitais SBC: https://meninas.sbc.org.br

[5] Translation: PHASE 1.

[6] Translation: PHASE 2.

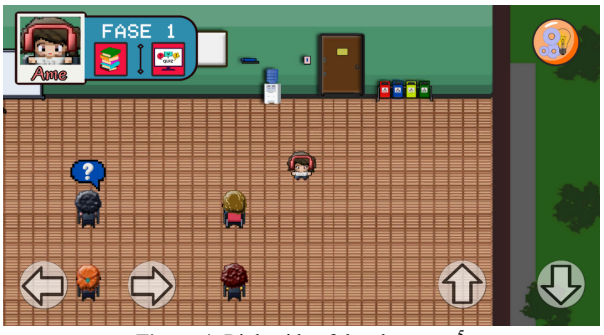

Figure 4. Right side of the classroom[5]

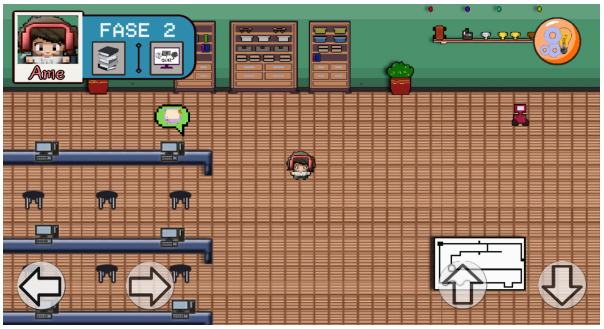

Figure 5. Left side of the classroom[6]

would be the only girl interested in this topic. Teacher Carlona, noticing her surprise, emphasizes that computing is not exclusive to boys and that girls can also work in the IT (Information Technology) field.

Next, the teacher asks the other girls in the class to introduce themselves to Ame. The first was Ana, a student passionate about calculations and rockets. Then, Rafaela spoke, who is enthusiastic about learning programming to create an electronic drum. Grace, who loves storytelling and was named after the scientist Grace Hopper, creator of the first 'human' computational languages, which enabled the computational interpretation of commands in English rather than just numbers and symbols. This incredible scientist helped popularize programming and opened many paths for the computational languages used today [Encyclopedia Britannica, 2023]. These interactions highlighted to Ame the diversity of interests and talents among the girls in the school's computer science course.

After meeting her new friends, the main character embarks on a journey through the Arduino universe. By interacting with different components, characters, and items along the way, she is guided through various parts of the game, experiencing a playful and enriching learning experience about hardware, software, and electronic components. Figure 6 presents the first nine levels of the game, which must be completed before reaching the final stage—the tenth—represented by a challenges screen. In this stage, the player will access tutorials for four projects, as illustrated in Figure 7. The game is available for *download* on the Android platform. Moreover, all the source code is accessible on GitHub[7], through the game's repository, which is part of the Meninas.comp organization.

[7]`https://github.com/meninas-comp-UnB/jogo-Arduino`
[8]Translation: PHASES.
[9]Translation: CHALLENGES.

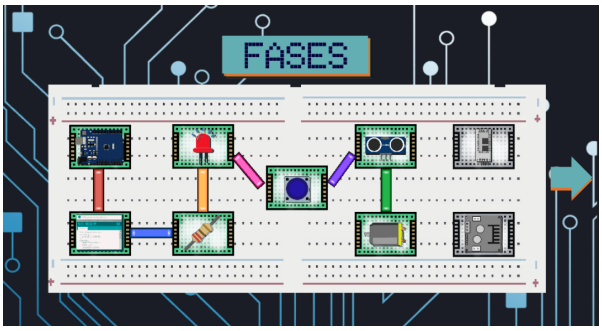

Figure 6. Game stages screen of *Code.Ino*, showing 7 currently unlocked stages[8]

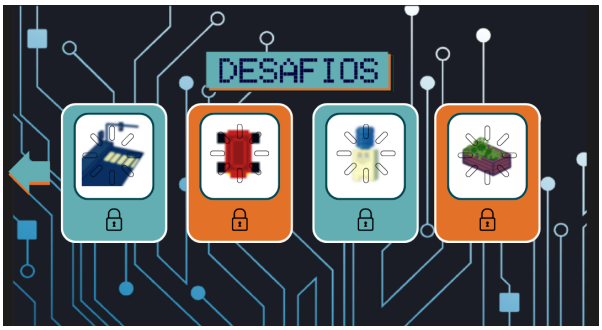

Figure 7. Screenshot of level 10 of the game *Code.Ino*, where the tutorials are locked[9]

4.1 Game Phases

The game takes place entirely in a classroom with a layout different from the conventional. One side features desks and chairs (Figure 4); and the other side has counters (Figure 5). In each level of the game, a component of Arduino is presented, along with elements related to its programming. Throughout the levels, various components are addressed, including hardware, software, resistors, LEDs, *breadboards*, buttons and switches, sensors, motors, *displays*, H-bridges, and communication modules. At the end of each level, the main character, Ame, must face a challenge composed of a questionnaire with options related to the content studied. If she scores equal to or above 3, the next level is unlocked via a *jumper* on the level selection screen, which symbolically 'connects' to the following stage. Figure 6 (FASES) presents the sequence of all levels in the *Code.Ino* game.

The screen shown in Figure 6 has only the first seven levels enabled, allowing for a connection between them. As the player completes each new level, the next level is enabled, and this screen is updated to show the player's current level. Figure 7 (DESAFIOS) shows the screen for stage 10, which the user will only see after completing the initial nine stages of the game. This screen contains the four challenges that the player must complete. Each challenge is a project that the player will build using Arduino, leveraging the knowledge acquired in the previous stages.

Figure 10 illustrates the flow of possibilities within the game, including the various screens, available options on each, the types of dialogues possible at each stage, and the unlocking system's operation. This visualization helps to understand the sequential and branching logic that structures the player's journey, highlighting how interactions influence the progression of narrative and mechanics. The unlocking system is directly linked to the progression through levels,

with each level characterized by a specific set of objectives and interactions. As the player advances, new possibilities are gradually unlocked. Additionally, the flow diagram in the figure highlights the interconnectedness of the levels, as one level depends on the knowledge acquired in the previous level. In early stages, dialogues are introductory and expository, while in intermediate and final stages, it is implied that the player is already building knowledge about the topic.

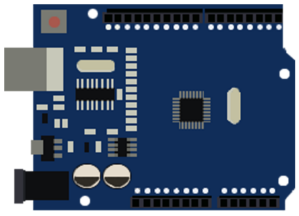

Figure 8. Arduino board.

Figure 9. Arduino IDE Screenshot.

The levels contained in the game are presented below to expose the content explored in each stage and the pedagogical objectives guiding its development. Each level was carefully planned to provide the player with a gradual learning experience, combining playful elements with fundamental concepts of computing. This step-by-step structure facilitates content assimilation while maintaining the player's interest and engagement throughout the narrative. So, the 10 stages of the *Code.Ino* game are:

- **Phase 1 - Hardware and Arduino Uno Board**: In this stage, with the support of the teacher and colleague Carol, Ame begins her journey into the world of electronics by learning about the architecture of the Arduino Uno board (Figure 8). The main components of the board are introduced, including the microcontroller, digital and analog ports, power pins, and the electrical limitations that must be respected during circuit development. Besides the technical content, this stage also introduces each of the classmates, presenting their stories and motivations for studying robotics;
- **Phase 2 - Software Fundamentals**: Under the guidance of the teacher and with the help of colleague Julia, Ame is introduced to the Arduino programming environment. She learns to use the IDE (Integrated Development Environment) and program in a language based on C++. The stage is illustrated with the IDE interface (Figure 9). It pays homage to the legacy of *Ada Lovelace*, recognized as the first programmer in history, for her studies on Charles Babbage's analytical engine [Encyclopedia Britannica, 2025];
- **Phase 3 - Resistors**: The teacher, along with colleague Ana, teaches Ame about the fundamentals of resistors, covering the color code, resistance calculation, and their applications in circuits with Arduino. This stage also highlights the life of *Hertha Marks Ayrton*, a British engineer and physicist whose research in electricity and resistance was essential for the advancement of electrical engineering [Gregersen, 2023];
- **Phase 4 - LEDs and Jumpers**: With the guidance of the teacher and colleague Rafaela, Ame learns about the operation of LEDs, the concept of polarity, and how to assemble simple circuits using jumpers, the narrative references the contributions of *Margaret Hamilton*, a software engineer responsible for developing the code for the Apollo 11 mission, which ensured the success of the Moon landing [Weinstock, 2016];
- **Phase 5 - Buttons and Switches**: At this stage, Ame learns from the teacher and Grace about various types of switches, the principles of digital logic, and how to utilize buttons and switches to control electronic circuits, this phase pays tribute to *Edith Clarke*, the first electrical engineer in the United States and a pioneer in applying mathematical methods to solve power transmission problems [National Inventors Hall of Fame, 2015];
- **Phase 6 - Sensors**: The teacher and colleague Alice guide Ame on a journey through sensors, exploring models for detecting temperature, humidity, and infrared, as well as reading and interpreting the collected data. This stage presents the inspiring story of *Katherine Johnson*, a NASA mathematician whose orbital trajectory calculations were essential for American space missions [Shetterly, 2016];
- **Phase 7 - Motors and H-Bridge**: With the support of the teacher and colleague Laura, Ame learns how to control DC motors using the H-bridge, an essential circuit for direction control in automated systems. This stage highlights the innovations of *Emily Davenport*, considered one of the first inventors of rotary electric motors, whose experiments were fundamental to the development of modern motors [Academia Lab, 2024];
- **Phase 8 - Displays**: Through teacher Carlona, Ame discovers the various types of displays, including LCD and LED models, and learns how to visually and organizationally present information collected by sensors. This stage highlights *Mary Lou Jepsen*, a scientist and engineer responsible for significant advances in image display technologies, including her work on the One Laptop per Child project [Jepsen, 2023];
- **Phase 9 - Communication Modules**: Finally, with the guidance of the teacher, Ame learns about wireless communication modules, such as Bluetooth. She understands the protocols involved, as well as how to integrate them with devices and remote controls. This stage pays homage to *Hedy Lamarr*, an actress and inventor who contributed to the development of the frequency spectrum foundation used in modern communication technologies, such as Wi-Fi and GPS [Website, 2024];
- **Phase 10 - Integrative Project**: It challenges the player to apply all the knowledge acquired. Processes such as requirements specification, creation of schematic di-

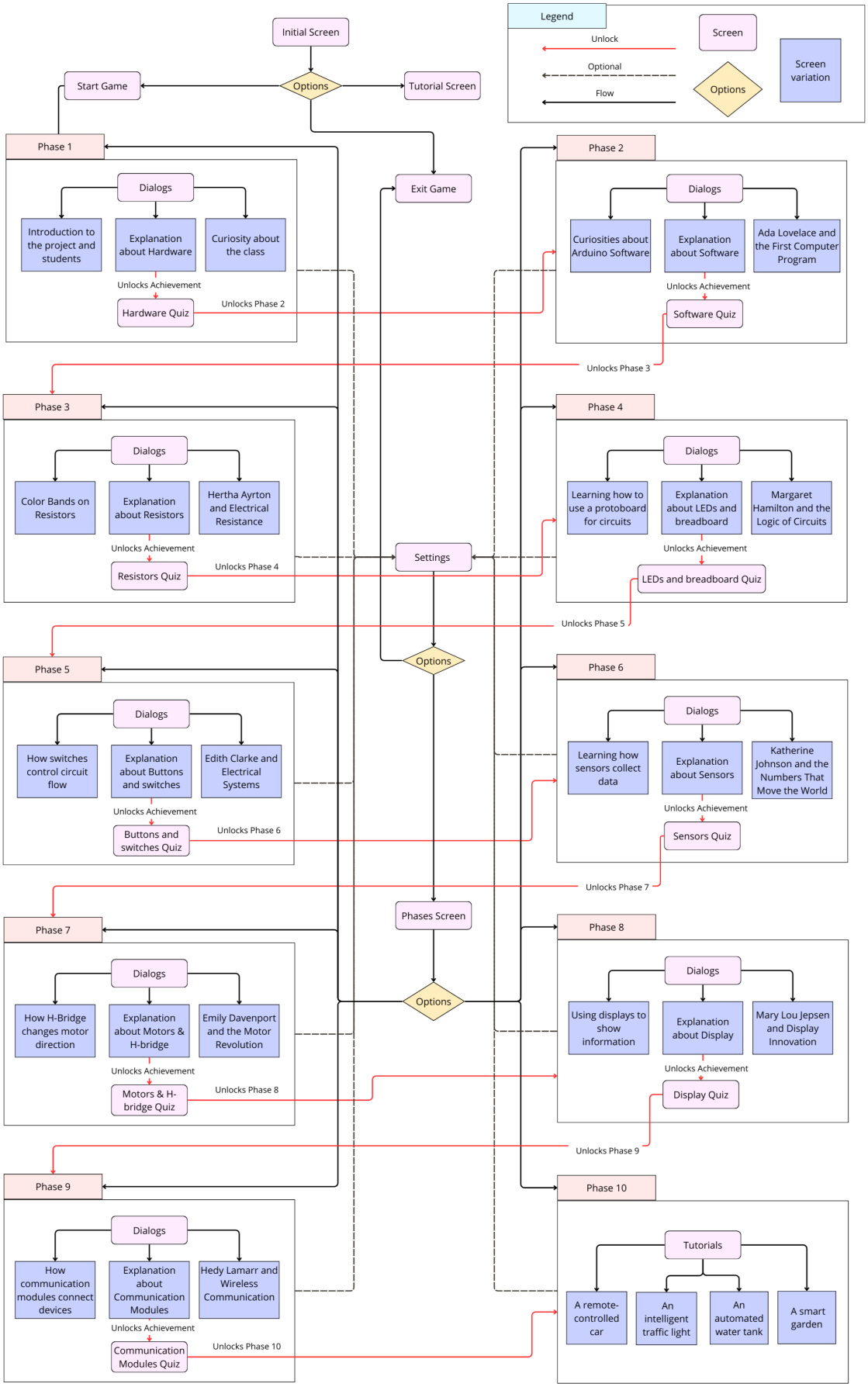

Figure 10. Game Flowchart.

agrams, virtual prototyping, and functional validation are presented. The projects include a remote-controlled car, an intelligent traffic light, an automated water tank, and a smart garden, all accompanied by technical documentation.

5 Methodology

The methodology employed in the *Code.Ino* game was designed to ensure playful and dynamic learning, where the player can use their curiosity and creativity to assimilate programming concepts, especially those related to Arduino. The game was developed to ensure the player's mobility, allowing it to be used both in school environments and at home. Thus, *Code.Ino* can be downloaded on a smartphone and played offline.

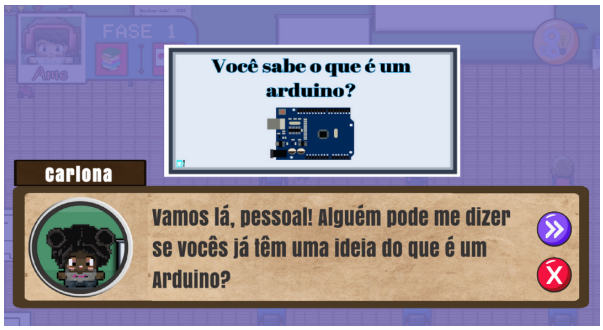

Figure 11. Example of a classroom dialogue[10]

Figure 12. Phase 2 quiz[11]

The game's creation process followed a clear order: first, the team defined the programming content to be taught, as the primary goal is education. The women to be honored were then strategically selected, with their contributions directly tied to the game's programming themes. This approach ensured that the tributes were integrated into the narrative and not just added details. The teaching-learning methodology applied in the game is structured into ten levels, as shown in Figure 6. Of these ten levels, the first nine are internally structured into two different stages to promote comprehensive and

Figure 13. Quiz result[12]

progressive learning. The first stage introduces relevant theoretical concepts through interactions with game characters, providing the fundamentals and principles that can be applied. The player also has access to study materials, such as explanatory texts and illustrative images, as shown in Figure 11.

In the second stage, the player is directed to a practical *quiz*, as shown in Figure 12. This quiz is conducted on a computer within the *virtual environment* of the game, serving as an assessment to verify understanding and retention of the theoretical knowledge acquired in the first stage. By achieving a minimum number of correct answers in the *quiz*, as shown in Figure 13, the player can advance to the next level of the game (as presented in Figures 6 and 7), thus maintaining progress in learning Arduino programming.

In the tenth and final level, *Code.Ino* will present a new type of challenge to the player. Instead of following the pattern of the previous nine stages, this level will focus on teaching how to use other *online* tools related to Arduino to develop a project from scratch. At this special stage, the player will be guided through various online tools available for Arduino programming and development, including learning about simulation software, online IDEs, virtual prototyping platforms, and other relevant resources.

A game that teaches programming is essential to make this skill accessible, transforming complex code into fun challenges. Its importance is heightened when it is in Portuguese, with slang and current customs, and includes Brazilian settings. This cultural identification creates a strong sense of belonging in the players, making learning more meaningful. Ultimately, this approach is a teaching strategy for digital inclusion, inspiring and empowering the new generation of developers in Brazil.

6 Ethical Procedures

The evaluation of the *Code.Ino* game was conducted in accordance with ethical principles to ensure the protection and privacy of all participants. Although approval from an Ethics Review Board has not yet been formally requested for this initial evaluation phase, several measures were adopted to uphold ethical standards throughout the research process.

Informed consent was obtained verbally from all participants before they engaged with the game and the online questionnaire. For participants who were minors, authorization was secured through their respective educational institutions. During this process, the objectives of the research were clearly explained, and it was emphasized that participa-

[10] Translations: (Top box) "Do you know what an arduino is?" (Dialogue box) "Let's go, everyone! Can anyone tell me if you already have an idea of what an Arduino is?"

[11] Translation of the quiz: (Question) "What does the word "void" mean?" (Options, from left to right) "It's a library", "It's a type of function", "It's a comment".

[12] Translation: "Congratulations on the achievement! You got 4 out of 5 questions right!". The buttons are "Jogar Novamente" (Play Again) and "Voltar para a sala" (Return to the classroom).

tion was voluntary and that they could withdraw at any time without any penalty.

To ensure the privacy and data protection of the participants, the evaluation questionnaire was designed to be anonymous. No personally identifiable information, such as names, personal documents, or contact details, was collected. The fully anonymized dataset generated during the study is publicly available to ensure transparency, as detailed in the 'Availability of data and materials' section. This approach guarantees the confidentiality of individual responses while allowing for the verification of the research findings.

7 Results

To evaluate the *demo* version of the *Code.Ino* game, which features two phases in its mobile version for Android, an online questionnaire survey was conducted. The primary objective was to perform a critical analysis of the gameplay and explore the game's potential as a tool for teaching Arduino programming. Over a period of 14 days, 55 participants engaged with the demo version and provided feedback. The analysis of the results was divided into two sections: the first focused on the participants' (students, teachers, and teaching assistants) perceptions of the game's effectiveness as a teaching-learning aid; the second examined the gameplay strategies employed within the game.

Respondents ranged in age from 11 to 63 years. Among them, 63.8% identified as cisgender women, 34.0% as cisgender men, and 2.2% as transgender men, as illustrated in Figure 14. Regarding education level, 51.9% were in Middle School, 33.3% in High School, and 14.8% had already completed undergraduate studies (see Figure 15). This composition allowed for a comprehensive evaluation, as 85.2% of the participants belonged to the game's target audience, while the remaining 14.8%, who had already graduated, offered a different perspective, analyzing how the game could have been useful during their school journey and its potential to help new generations learn programming. Furthermore, the fact that 63.8% of the participants were women highlights the game's impact on this audience, reinforcing its relevance in promoting inclusion and female representation in the field of technology.

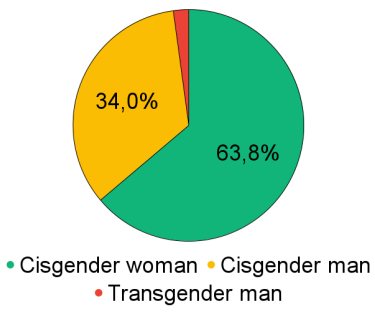

Figure 14. Players' Gender.

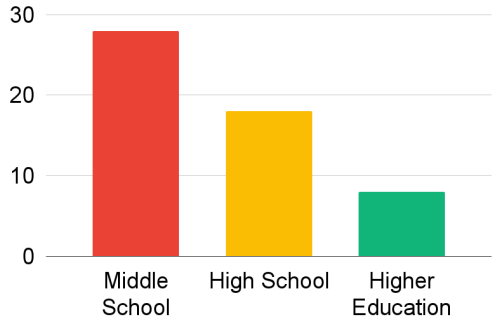

Figure 15. Level of education.

7.1 Player Perception

To determine whether the game should be targeted toward a specific group of players, the question was asked: "Is the game intended for a particular type of audience?" As shown in Figure 16, a significant majority of respondents answered "yes" with a higher number of girls (approximately 21) than boys (around 11) giving this response. For those who answered "yes," the follow-up question was, "For whom was the game developed?" Most respondents indicated that the game was suitable for beginners in programming and students.

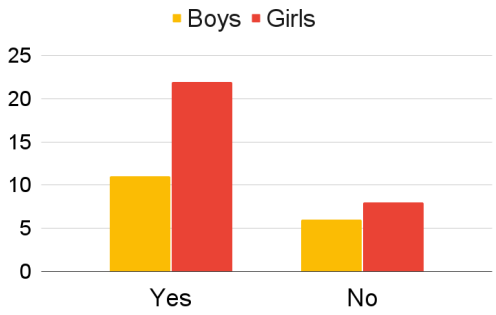

Figure 16. Specific audience.

Regarding players' perceptions of the female protagonist, the question was: "What did you think about the main character being a girl?" Responses were highly positive. As detailed in Figure 17, both boys and girls rated the experience predominantly as "Very Good" or "Good." In the "Very Good" category, a higher number of girls (approximately 25) than boys (around 21) were observed. For the "Good" rating, the distribution was more balanced, with a slight majority of boys' responses. Furthermore, when asked about their feelings playing with a female character, girls reported feeling represented and that the character was necessary, while most boys found the experience to be enjoyable and relaxing.

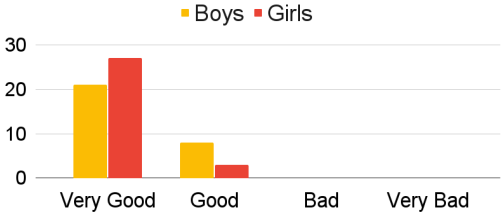

Figure 17. The main character being a girl.

The survey also evaluated the idea of having a digital game to teach Arduino. The responses were positive, with 76.7% of students stating it was perfect, and 23.3% saying it was good. Furthermore, they were asked about their thoughts on how the game was organized. The responses were optimistic, as the vast majority (92.3%) stated they found the game very good.

Thus, the *Code.Ino* game proposal was well received by students and teachers, as 75% of the boys rated it between 9 and 10, while the girls rated it between 8 and 10, with 76.9% giving a perfect score of 10. Although 63.8% of participants were women, the evaluation showed that the approach was well-received by all genders, with male students reporting that they felt comfortable with the narrative. Next, the question was asked exclusively of the students: 'What did you think about studying Arduino through a game?' The result was highly positive, as 100% considered it a playful, creative, original, engaging, and didactic tool for the teaching-learning process. The evaluation also gathered specific feedback from educators. Among the participants, eight identified as robotics teachers, all of whom hold higher education degrees. When this group of teachers and monitors was asked whether 'the game would help students learn Arduino?', all respondents (100%) answered yes. Moreover, 100% of the players (teachers and students) would recommend this game to a friend.

7.2 Analysis of Interface and Strategy

During this evaluation stage, questions were asked about the fact that the game consists of 10 levels, combining theory and practice. The response options were very good, good, bad, and very bad. The results showed that 75% of respondents found it very good, and 25% found it good. Next, the participants were also asked about their opinion on the *quiz* in each level. For this question, the results indicated that 87.5% thought it was very good, and 12.5% thought it was good. Finally, suggestions for improving the game were requested, and some responses suggested adding audio to the game, such as reading playback with audio, including assembled circuits, and adding boys to the game to reach all genders.

Regarding the color palette, most students did not perceive a distinction between colors associated with females and those associated with males. Concerning the visual aspect of the game, 75% of the girls found the game creative, and 15.4% found it simple. For the boys, 83.3% thought the game was creative, and 16.7% considered it modest. Additionally, respondents were asked what they thought about the game being named *Code.Ino*, and the responses were positive, indicating that they found it creative, fun, and intuitive.

Thus, it is evident that electronic games are an integral part of young people's lives, and learning programming through games presents an opportunity for teachers and students to utilize a new learning mechanism. In this way, using *Code.Ino* in programming education offers several advantages, especially in the context of basic education. As a playful and interactive tool, the game stimulates students' interest and curiosity, making learning more engaging and accessible. Furthermore, it promotes active learning, allowing students to test, make mistakes, and correct their code in a safe and fun environment.

7.3 Future Steps

As a continuation of this project, it is planned to expand the game's functionalities, such as adding a button in the shape of a backpack, as shown in Figure 18. The idea is that within this backpack, there will be some items, such as a notebook in which the player can review what has been learned through a brief summary, as seen in Figure 19. Other buttons to add would be audio support, screen readers, background music, and contrast settings.

Figure 18. Room screen with backpack button[13]

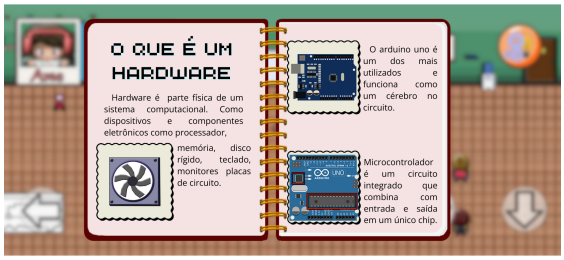

Figure 19. Notebook screen[14]

Additionally, new environments are intended to be added, such as the Department of Computer Science at UnB, which can be seen in Figure 20, and other campus buildings to give students a greater sense of proximity to the university environment. There are also plans to include other languages and narrative elements to deepen the player's experience. Moreover, performance optimizations and adaptations for different platforms will be explored, aiming to broaden the audience reach.

8 Conclusion

This article presented the digital game *Code.Ino*, which is a game developed by a group of female undergraduate students

[13] Translation: PHASE 1.

[14] Translation of the notebook: (Left Page Title) "WHAT IS HARDWARE". (Left Page Body) "Hardware is the physical part of a computational system, such as devices and electronic components like the processor, memory, hard disk, keyboard, monitors, circuit boards." (Right Page, Top) "The Arduino Uno is one of the most used and it functions as the brain of the circuit." (Right Page, Bottom) "A microcontroller is an integrated circuit that combines input and output on a single chip."

Figure 20. Department of Computer Science at UnB.

who are part of a Brazilian project called Meninas.comp, which is part of the Meninas Digitais program, which is of national interest to the computing community. It aims to spark girl's interest in pursuing careers in Information and Communication Technology. The primary goal is to teach Arduino and programming playfully and engagingly. The game is based on the idea of activating, at each level, people's curiosity to learn more about the world of technology.

Code.Ino also the understanding of fundamental concepts of programming and electronics with Arduino, intuitively connecting theory and practice. The accessibility of *Code.Ino* via *smartphones* further broadens the initiative's reach, especially among young audiences, contributing to the democratization of technological knowledge and the training of a new generation of creative and confident programmers.

However, the relevance of the *Code.Ino* game goes beyond its pedagogical proposal; by portraying the leading role of women who contributed to significant discoveries and advances in the evolution of Science, the game promotes the appreciation of diversity and the recognition of important female figures in the history of technology and science. This approach is crucial for expanding the understanding of women's roles in the STEM field and for inspiring new generations to become interested in these disciplines. Knowing and valuing these success stories is a powerful strategy to encourage female participation, combat stereotypes, and promote greater gender equity in the scientific and technological universe. In this way, *Code.Ino* contributes not only to teaching programming but also to building a more inclusive and representative culture in the STEM field.

Therefore, the motivational factor, expressed by students during the game evaluation, is predominant among the aspects that confirm the ability to teach Arduino programming. Besides feeling motivated, students have the opportunity to practice their creativity with the Arduino platform. Thus, the *Code.Ino* game aims to teach programming in a fun way, encouraging more people to engage with this area. However, to enhance the player's experience, in addition to the future steps described, it is planned to add more mini-challenges to each level that can serve as training exercises and include sound effects.

Declarations

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Authors' Contributions

Aleteia Araujo, **Bianca P. Castro**, **Hanani E. F. Soares**, and **Maristela Holanda** contributed equally to the writing of this manuscript. **Bianca P. Castro** and **Hanani E. F. Soares** were responsible for all coding of the *Code.Ino* game. **Aleteia Araujo** and **Maristela Holanda** leaded the analyses and visualizations. All authors read and approved the final manuscript.

Competing interests

The authors declare they have no competing interests.

Availability of data and materials

The datasets generated and/or analyzed during the current study are available in: `https://zenodo.org/records/15312307`

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